Maximizing TDRS Command Load Lifetime

The GNC software onboard ISS utilizes TDRS command loads, and a simplistic model of TDRS orbital motion to generate onboard TDRS state vectors. Each TDRS command load contains five "invariant" orbital elements which serve as inputs to the onboard propagation algorithm. These elements include semi-major axis, inclination, time of last ascending node crossing, right ascension of ascending node, and mean motion.

Running parallel to the onboard software is the TDRS Command Builder Tool application, located in the JSC Mission Control Center. The TDRS Command Builder Tool is responsible for building the TDRS command loads using a ground TDRS state vector, mirroring the onboard propagation algorithm, and assessing the fidelity of current TDRS command loads onboard ISS. The tool works by extracting a ground state vector at a given time from a current TDRS ephemeris, and then calculating the corresponding "onboard" TDRS state vector at the same time using the current onboard TDRS command load. The tool then performs a comparison between these two vectors and displays the relative differences in the command builder tool GUI. If the RSS position difference between these two vectors exceeds the tolerable limits, a new command load is built using the ground state vector and uplinked to ISS. A command load's lifetime is therefore defined as the time from when a command load is built to the time the RSS position difference exceeds the tolerable limit.

From the outset of TDRS command load operations (STS-98), command load lifetime was limited to approximately one week due to the simplicity of both the onboard propagation algorithm, and the algorithm used by the command builder tool to generate the invariant orbital elements. It was soon desired to extend command load lifetime in order to minimize potential risk due to frequent ISS commanding. Initial studies indicated that command load lifetime was most sensitive to changes in mean motion. Finding a suitable value for mean motion was therefore the key to achieving this goal.

This goal was eventually realized through development of an Excel spreadsheet tool called EMMIE (Excel Mean Motion Interactive Estimation). EMMIE utilizes ground ephemeris nodal data to perform a least-squares fit to inferred mean anomaly as a function of time, thus generating an initial estimate for mean motion. This mean motion in turn drives a plot of estimated downtrack position difference versus time. The user can then manually iterate the mean motion, and determine an optimal value that will maximize command load lifetime.

Once this optimal value is determined, the mean motion initially calculated by the command builder tool is overwritten with the new optimal value, and the command load is built for uplink to ISS. EMMIE also provides the capability for command load lifetime to be tracked through multiple TDRS ephemeris updates. Using EMMIE, TDRS command load lifetimes of approximately 30 days have been achieved.